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Field Verification of New and Novel Fracture Stimulation Technologies for the Revitalization of Existing Underground Gas Storage Wells

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4B.2 Field Verification of New and Novel Fracture Stimulation Technologies for the Revitalization of Existing Underground Gas Storage Wells

CONTRACT INFORMATION

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Period of Performance September 27, 1994 to September 26, 1998

Schedule and Milestones

FY95 Program Schedule

	S	O	N	D	J	F	M	A	M	J	J	A
Provide NEPA Information						—						
Review Existing Technology		—	—	—								
Locate Gas Storage Cos.		—	—	—								
Obtain Test Site Approvals					—	—						
Develop Work Plans							—	—	—			
Execute & Report on Field Tests										—	—	—

OBJECTIVES

The objective of this research project is to demonstrate improved, less costly means for restoring injection and withdrawal capability in existing gas storage wells. This will be accomplished by field testing alternative fracture stimulation techniques that incorporate the latest in technology with a concentration on cost-effective, small-scale well treatments.

BACKGROUND INFORMATION

An improved, more efficient natural gas transmission and deliverability system will be essential for supporting the expected growth in U.S. gas demand in the coming decades. The role of gas storage in this system will be particularly important as much of the new natural gas use will be cyclic in nature, coming from the residential sector of the north-east with high winter season gas needs, and from new power generation facilities throughout the U.S. with high peak-day requirements. The most cost-effective means for providing this additional seasonal storage capacity and peak-day deliverability is to improve the efficiency of the existing gas storage system. Recognizing the economic realities of FERC Order 636 and an unbundled storage system, the National Petroleum Council clearly set forth industry's views on this issue when they stated[1]:

The first step in reducing costs is "minimizing new facility requirements through the more efficient use of existing facilities and the utilization of new technology."

Thus, a high priority is to improve the efficiency of the 370 gas storage facilities and the 17,000 existing gas storage wells. These facilities and wells currently contain almost 4 Tcf of working gas, 24 Bcf per day of seasonal capability and 54 Bcf per day of peak-day deliverability[2]. The goal is to increase current capability, and, importantly, to counteract the persistent 5.2% loss in annual well deliverability that is being observed by industry[3].

With these annual deliverability losses, it is now becoming obvious to gas storage operators that most wells are not physically performing up to their deliverability potential, but they currently do not have an entirely effective remediation solution. Industry's current deliverability enhancement techniques focus mainly on simple well remediation methods and infill drilling. The typical remediation treatment involves cleaning the wellbore by mechanical means or by blowing/washing, acidizing, and/or re-perforating. Field evidence suggests that these treatments, at best, temporarily restore gas deliverability. As a result, costly infill drilling is the main approach used to offset the decline in gas storage deliverability, which requires annual capital expenditures of $65 to $70 million[2]. Alternative, more effective and durable stimulation methods would significantly lower these costs.

Fracturing technologies, now routinely employed in the oil and gas production industry as a means of stimulating well performance, hold great potential to meet this need. These technologies have not been widely utilized by the gas storage industry, however, because of concerns that created fractures may penetrate the reservoir seal and promote leakage. Through the utilization and advanced treatment design and implementation procedures, these methods can be safely applied to gas storage reservoirs.

The economic impact of successfully transferring these well revitalization techniques to the gas storage industry would be substantial. If the average decline rate of storage well deliverability could be cut by one-third, from 5.2% to 3.5% per year (by effectively fracturing existing wells), such that infill well drilling could be curtailed, the industry would save one-half to two-thirds of what it currently spends offsetting deliverability decline, translating into an industry savings of $50-70 million per year. Hence a substantial RD&D opportunity exists to promote and accelerate the transfer of this technology.

DOE/METC has responded to this industry priority and RD&D opportunity by recognizing it in their Natural Gas Plan and by initiating a major, multi-year field demonstration program designed to demonstrate the application of fracturing to revitalize deliverability from existing gas storage wells. The program's key features are its broad consideration of various new and novel fracturing technologies and its joint effort with and co-funding by industry.

PROJECT DESCRIPTION

The approach that will be utilized for this RD&D project is to test up to five new and novel well stimulation technologies in a series of field demonstrations. A total of nine such tests will be performed during 1995, 1996 and 1997, with each project examining one specific technique. By incorporating three test wells and one control well into each test site, we will be able to rigorously evaluate the five well stimulation technologies being investigated in this project:

- Tip screen-out hydraulic fracturing
- Hydraulic fracturing with liquid carbon dioxide
- Hydraulic fracturing with (proppantless) gaseous nitrogen
- Propellant fracturing
- Nitrogen pulse fracturing

In order to achieve the objectives and requirements of this project, the RD&D effort must possess four key elements (Figure 1):

- A clear demonstration of the effectiveness of fracturing to revitalize the deliverability of gas storage wells, as compared to conventional industry well remediation practices, and the durability of deliverability improvement.

- State-of-the-art fracture treatment design procedures to maximize the potential for stimulation success and to predict the potential for caprock damage.

- A diagnostics program that identifies possible damage to the reservoir seal, both during fracturing (such that it can be immediately arrested) and afterwards.

- Effective deployment of the technology to industry.

These elements, and ARI's approach to providing them, are described below.

Evaluating Deliverability Improvement

A key objective of this RD&D project is to demonstrate the effectiveness of fracturing technologies to improve the deliverability of gas storage wells. Well deliverability is primarily a function of reservoir permeability and wellbore skin effect, the skin being a theoretical measure of the degree of damage or stimulation existing around a wellbore. Since bulk reservoir permeability is unlikely to change significantly with time, skin is the fundamental determinant for deliverability in gas storage wells. Pressure transient testing, which involves the injection or withdrawal of fluids at either a constant pressure or rate, followed by a shut-in period, can be used to quantify the skin value. This technique, therefore is our proposed approach to well deliverability evaluation.

ARI will utilize gas injection/falloff and/or production/buildup testing as evaluation methods, depending upon which technique best suits the needs of each cooperative research partner. Both methods are equally applicable to the needs of this RD&D project, and the flexibility to utilize either approach will allow ARI better to integrate this project with the routine operations of operators. Pre- and post-treatment testing will be performed to evaluate stimulation effectiveness, as well as one year later to measure the durability of the stimulation.

To be successful this project must also compare the deliverability enhancement achieved with the new and novel fracturing technologies to traditional gas storage well remediation techniques in a clear, direct manner. Such clarity between the effectiveness of different stimulation treatments can only be adequately achieved in a controlled, carefully monitored environment in which all wells are evaluated using consistent diagnosis methodologies. Therefore to meet this objective, a control well will be incorporated into each test site, which will be stimulated using the operator's current practices, for direct comparison to the fracturing test wells. This control well

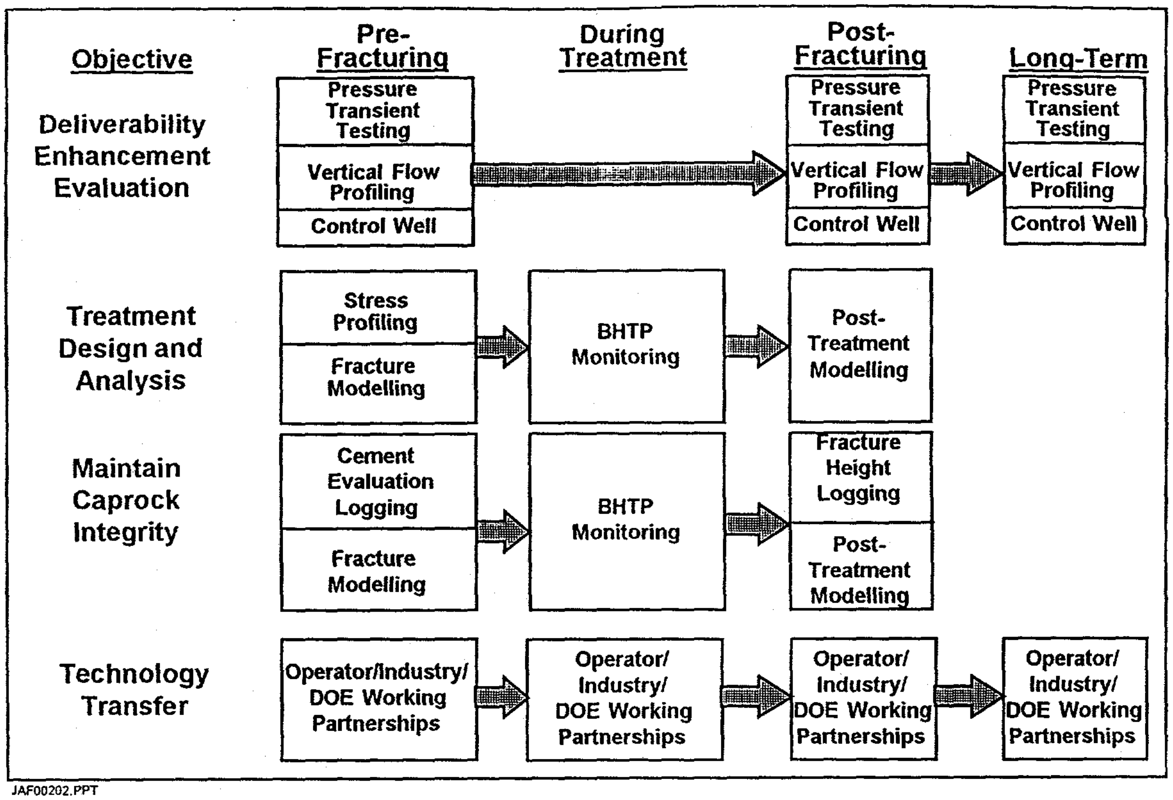

Figure 1. Key Elements of ARI's Technical Approach

will be fully tested and studied in a parallel manner as the fracture test wells, which includes pre- and post-stimulation pressure transient testing to quantify immediate deliverability enhancement as a result of the treatment, as well as testing one year later to evaluate any longer-term changes in well deliverability.

Implementation of Advanced Fracturing Technologies

A critical aspect of this project will be to provide expert design and analysis capabilities for these advanced fracturing technologies. Mike Smith, the pioneer of tip screenout fracturing, the co-developer of the industry-standard Nolte-Smith procedure for the analysis of treatment pressures, and author of the pseudo-3D fracturing simulator STIMPLAN and the mini-frac analysis software FRACTEST, brings unparalleled design and analysis expertise in the area of novel hydraulic fracturing technology. In addition, John Schatz, as author of the leading pulse fracturing simulator PULSFRAC, and a pioneer in the analysis of pulse fracturing treating pressures brings similar expertise in the area of fracturing technology. These intellectual and software resources will be utilized to demonstrate that each fracturing technology being evaluated as part of this project can be confidently and safely designed and implemented.

Maintaining Caprock Integrity

As mentioned previously, the potential for caprock damage is the industry's number one concern with fracturing technology, and the prevention of caprock damage and its detection if it does occur, a priority of this RD&D program. The prevention of caprock damage will be firstly achieved through careful treatment design and modelling. An understanding of rock mechanical properties and in-situ state of stress will be of critical importance during this process. To obtain these parameters at each test site acoustic logs will be obtained and processed to determine these parameters. Available fracturing, stress test and rock mechanical properties data will be used to correlate the log information to observed values. Fracture simulation studies will be performed to determine how likely an occurrence of fracture breakout is.

Deploying Technology to Industry

Deploying the findings of this RD&D effort to industry will be an equally important element of the program. Without this, DOE's objective of reducing the cost of deliverability enhancement will not be achieved.

This project, being a field verification and demonstration effort, by its very nature possesses an excellent technology transfer component. By working cooperatively with industry in the field, operators will gain a firsthand knowledge of the technology and its application for gas storage. For this reason, the overall project will involve many different operators, as opposed to a select few. Due to the relatively small gas storage community, the nine field tests proposed in this project have the potential to impact of a large percent of the gas storage capacity of the U.S.

RESULTS

Work performed to date has been primarily related to acquisition of test sites for the 1995 RD&D program. To facilitate this, all gas storage companies were contacted and asked if they were interested in providing a test site. Industry response was strong. Forty one companies representing 71% of all U.S. working gas capacity and 75% of all I/W wells indicated an interest to participate in the project. A preliminary screening of potential sites resulted in a list of twelve from which to select the three sites needed for the 1995 RD&D program (Table 1).

A number of technical criteria were then used to further screen the test sites, including consistency with overall project objectives, and simplicity (both geologic and operational) for this first year of the project. Six test sites were deferred on this basis, as shown in Table 2.

From the resulting immediate list of six potential sites, final screening yielded three primary sites and two back-up sites as presented in Table 3, with two planned for demonstrating tip-screenout fracturing and one for fracturing with liquid carbon dioxide. The criteria for final screening included indications that the field would respond positively to fracturing (i.e., has a high permeability and the wells were "damaged"), availability of pre-existing data which would benefit the project, and the consistency of the work plan with the operator's intentions for the field.

Relevant data on the three test sites are presented in Table 4. This mix of projects will provide a comparison of tip-screenout and liquid carbon dioxide fracturing in the sandstone storage formations of Pennsylvania, and a comparison of tip-screenout fracturing in high and low deliverability gas storage fields.

FUTURE WORK

During 1995, the two tip-screenout and one liquid carbon dioxide fracturing RD&D programs presented above will be performed and reported upon. Additional test sites will also be selected for further demonstrating the application of these and other fracture technologies (e.g., propellant, nitrogen, pulse) in 1996 and 1997.

Table 1. Initial List of Potential Test Sites

Company	Field	State
Columbia Natural Gas	Crawford Victory "B" Donegal	Ohio W. Virginia Pennsylvania
KN Energy	Huntsman Wolf Creek Loop	Nebraska Colorado Texas
Consumers Power	Overisel	Michigan
National Fuel Gas Supply	Galbraith	Pennsylvania
Natural Gas Pipeline	Cooks Mills Sayre North Lansing	Illinois Oklahoma Texas
Southern California Gas	West Montebello	California

Table 2. Test Sites Deferred from 1995 Program

Field	Reason
Crawford	Proposed treatment were for new wells
Wolf Creek	Complex geology; faulted, low permeability, naturally fractured
Loop	Horizontal well, not representative of older well population
Sayre	Problem was with injection, not withdrawal
North Lansing	Facilities limitations restricted deliverability enhancement opportunity
West Montebello	Dual completions, operational complexity

Table 3. Final 1995 Test Site Selections

	Field	Company	Initial Treatment Selection
Primary Sites	Donegal	Columbia Gas Transmission	Tip-Screenout
	Galbraith	National Fuel Gas Supply	Liquid Carbon Dioxide
	Huntsman	KN Energy	Tip-Screenout
Secondary Sites	Cooks Mills	Natural Gas Pipeline	Tip-Screenout
	Overisel	Consumers Power	Undecided

Table 4. 1995 Test Site Descriptions

	Donegal (Tip-Screenout)	Galbraith (Liquid CO_2)	Huntsman (Tip-Screenout)
State	Pennsylvania	Pennsylvania	Nebraska
Formation	Gordon Stray	1st Sheffield	Third Dakota "J"
Lithology	Sandstone	Sandstone	Sandstone
Age	Devonian	Devonian	Cretaceous
Reservoir Type	Depleted Gas	Depleted Gas	Depleted Gas
Depth	2600 ft.	2800 ft.	4800 ft.
Thickness	10 ft.	25 ft.	30 ft.
No. I/W wells	112	26	18
Ultimate Storage Capability (Bcf)	9.9	1.9	39.5
Maximum Field Deliverability (MMCF/day)	223	20	101
Maximum Per-Well Deliverability (MMCF/day/well)	2.0	0.8	5.6
Maximum Storage Pressure (psi)	1260	620	1170

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1. Potential for Gas in the United States, Washington, D.C.; National Petroleum Council, 1992.

2. Survey of Gas Storage Facilities in the United States and Canada, 1993, Arlington, VA; American Gas Association, Operating Section Report, 1993.

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